

The Dirac equation in general relativity

A guide for calculations

Peter Collas¹ and David Klein²

(September 7, 2018)

Abstract

In these informal lecture notes we outline different approaches used in doing calculations involving the Dirac equation in curved spacetime. We have tried to clarify the subject by carefully pointing out the various conventions used and by including several examples from textbooks and the existing literature. In addition some basic material has been included in the appendices. It is our hope that graduate students and other researchers will find these notes useful.

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Dirac Equations In General Relativity

Peter Collas, David Klein



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General Theory of Relativity P. A.M. Dirac, 1996-01-28 Einstein's general theory of relativity requires a curved space for the description of the physical world. If one wishes to go beyond superficial discussions of the physical relations involved, one needs to set up precise equations for handling curved space. The well-established mathematical technique that accomplishes this is clearly described in this classic book by Nobel Laureate P. A. M. Dirac. Based on a series of lectures given by Dirac at Florida State University and intended for the advanced undergraduate, *General Theory of Relativity* comprises thirty-five compact chapters that take the reader point by point through the necessary steps for understanding general relativity.

The Dirac Equation in Curved Spacetime Peter Collas, David Klein, 2019-03-21 This book explains and develops the Dirac equation in the context of general relativistic quantum mechanics in a range of spacetime dimensions. It clarifies the subject by carefully pointing out the various conventions used and explaining how they are related to each other. The prerequisites are familiarity with general relativity and an exposure to the Dirac equation at the level of special relativistic quantum mechanics, but a review of this latter topic is given in the first chapter as a reference and framework for the physical interpretations that follow. Worked examples and exercises with solutions are provided. Appendices include reviews of topics used in the body of the text. This book should benefit researchers and graduate students in general relativity and in condensed matter. *Dirac equations in general relativity* Jan Aroldus Schouten, 1931

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Dirac Equations in General Relativity Jan Arnoldus Schouten, 1931 **From the Lorentz Transformation to the Dirac Equation** K. Davies, Daniel Nydick, 2015-11-07 This book on Special Relativity with unique chapters on the Dirac equation and General Relativity is especially suitable for a one-semester undergraduate physics course on Special Relativity with perhaps some coverage of the qualitative features of General Relativity. It can also be used in a combination of undergraduate courses including modern physics, particle physics, optics, and Quantum Mechanics, or in classical mechanics at the physics graduate level. The book also includes coverage of the history of relativity, particularly with respect to developments in electricity and magnetism, particle physics, and cosmology. *From the Lorentz*

Transformation to the Dirac Equation Daniel S. Nydick, K. Thomas R. Davies, 2020-05-25 This book on Special Relativity with

unique chapters on the Dirac equation and General Relativity is especially suitable for a one semester undergraduate physics course on Special Relativity with perhaps some coverage of the qualitative features of General Relativity It can also be used in a combination of undergraduate courses including modern physics particle physics optics and Quantum Mechanics or in classical mechanics at the physics graduate level The book also includes coverage of the history of relativity particularly with respect to developments in electricity and magnetism particle physics and cosmology This is the revised second edition

The Dirac Equation Bernd Thaller, 2013-12-01 Ever since its invention in 1929 the Dirac equation has played a fundamental role in various areas of modern physics and mathematics Its applications are so widespread that a description of all aspects cannot be done with sufficient depth within a single volume In this book the emphasis is on the role of the Dirac equation in the relativistic quantum mechanics of spin 1/2 particles We cover the range from the description of a single free particle to the external field problem in quantum electrodynamics Relativistic quantum mechanics is the historical origin of the Dirac equation and has become a fixed part of the education of theoretical physicists There are some famous textbooks covering this area Since the appearance of these standard texts many books both physical and mathematical on the non relativistic Schrodinger equation have been published but only very few on the Dirac equation I wrote this book because I felt that a modern comprehensive presentation of Dirac's electron theory satisfying some basic requirements of mathematical rigor was still missing

The Dirac Equation and its Solutions Vladislav G. Bagrov, Dmitry Gitman, 2014-08-20 The Dirac equation is of fundamental importance for relativistic quantum mechanics and quantum electrodynamics In relativistic quantum mechanics the Dirac equation is referred to as one particle wave equation of motion for electron in an external electromagnetic field In quantum electrodynamics exact solutions of this equation are needed to treat the interaction between the electron and the external field exactly In this monograph all propagators of a particle i.e. the various Green's functions are constructed in a certain way by using exact solutions of the Dirac equation

General Relativity and the Dirac Equation Thomas Brennan, 2019-08-31 *The Many Faces of Maxwell, Dirac and Einstein Equations* Waldyr A. Rodrigues, Jr, Edmundo Capelas de Oliveira, 2016-04-26 This book is an exposition of the algebra and calculus of differential forms of the Clifford and Spin Clifford bundle formalisms and of vistas to a formulation of important concepts of differential geometry indispensable for an in depth understanding of space time physics The formalism discloses the hidden geometrical nature of spinor fields Maxwell Dirac and Einstein fields are shown to have representatives by objects of the same mathematical nature namely sections of an appropriate Clifford bundle This approach reveals unity in diversity and suggests relationships that are hidden in the standard formalisms and opens new paths for research This thoroughly revised second edition also adds three new chapters on the Clifford bundle approach to the Riemannian or semi Riemannian differential geometry of branes on Komar currents in the context of the General Relativity theory and an analysis of the similarities and main differences between Dirac Majorana and ELKO spinor fields The exercises with solutions the comprehensive list of

mathematical symbols and the list of acronyms and abbreviations are provided for self study for students as well as for classes From the reviews of the first edition The text is written in a very readable manner and is complemented with plenty of worked out exercises which are in the style of extended examples their book could also serve as a textbook for graduate students in physics or mathematics Alberto Molgado Mathematical Reviews 2008 k Essays in General Relativity Frank J. Tipler, 2013-10-22 Essays in General Relativity A Festschrift for Abraham Taub is collection of essays to honor Professor Abraham H Taub on the occasion of his retirement from the mathematics faculty of the University of California at Berkeley Relativistic hydrodynamics has always been a subject dear to Taub s heart In fact many basic results on special relativistic fluid flows are due to him and he has been a major contributor to the study of fluid flows near shocks The book contains 16 chapters and begins with a discussion of a geometrical approach to general relativity This is followed by separate chapters that examine the topology of the space time manifold representing a stellar model the notion of an external return in the context of general relativity and the standard two surface integral formulation of gravitational energy and momentum Subsequent chapters deal with tidal forces in a highly asymmetric Taub universe derivation of theoretical upper limits on the strengths of the gravitational waves that bathe the Earth and a new formulation of Lagrangian general relativistic hydrodynamics **Equations of Motion in Relativistic Gravity** Dirk Puetzfeld, Claus Lämmerzahl, Bernard Schutz, 2015-06-01 The present volume aims to be a comprehensive survey on the derivation of the equations of motion both in General Relativity as well as in alternative gravity theories The topics covered range from the description of test bodies to self gravitating heavy bodies to current and future observations Emphasis is put on the coverage of various approximation methods e g multipolar post Newtonian self force methods which are extensively used in the context of the relativistic problem of motion Applications discussed in this volume range from the motion of binary systems and the gravitational waves emitted by such systems to observations of the galactic center In particular the impact of choices at a fundamental theoretical level on the interpretation of experiments is highlighted This book provides a broad and up to date status report which will not only be of value for the experts working in this field but also may serve as a guideline for students with background in General Relativity who like to enter this field Classical General Relativity Subrahmanyan Chandrasekhar, 1993 Because of the vicissitudes of history the general theory of relativity has never been consistently explored to ascertain whether in its realm of exact validity it predicts phenomena which have no counterparts in the Newtonian limit that is in the limit in which the velocity of light may be considered infinite Thus while recent interest in physics has concentrated on such frontier areas as quantum gravity and cosmology there has also been a quiet but steady progress in the classical domain The five papers collected in this volume and presented under the editorship of the famed Nobel Laureate S Chandrasekhar illustrate the nature of these advances Each of them represents developments in areas both of physics and mathematics which disclose unanticipated findings that illustrate the special character of work in these areas

Astrophysicists and mathematical relativists will welcome this unique look at ongoing research

Nuclear Science Abstracts, 1975 **Solution of the Dirac Equation in Non-Asymptotically Flat Geometries** Izzet Sakalli, 2011-04 The Dirac equation a relativistic quantum mechanical wave equation invented by Paul Dirac in 1928 originally designed to overcome the negative probability problem arising in the Klein Gordon s scalar wave equation The Dirac equation is fully consistent with the principles of quantum mechanics and largely in accordance with the theory of General Relativity Paul Dirac s original equation can be modified to an advanced form in order to have the behaviors of the fermions in any curved spacetime In this regard the pioneering work of the Dirac equation in the asymptotically flat spacetime around a Kerr black hole was done by Nobel laureate Subrahmanyan Chandrasekhar in 1976 After Chandrasekhar progress was made to analyzing the Dirac equation in a non asymptotically flat geometry which is now a major focus of attention in Einstein s gravity theory enriched with various fields like Maxwell Yang Mills Born Infeld etc Izzet Sakalli one of the researchers of the Dirac equation develops and explains some methods about how one separates and solves the Dirac equation in non asymptotically flat geometry

The Special Theory of Relativity Anadijiban Das, 2012-12-06 Based on courses taught at the University of Dublin Carnegie Mellon University and mostly at Simon Fraser University this book presents the special theory of relativity from a mathematical point of view It begins with the axioms of the Minkowski vector space and the flat spacetime manifold Then it discusses the kinematics of special relativity in terms of Lorentz transformations and treats the group structure of Lorentz transformations Extending the discussion to spinors the author shows how a unimodular mapping of spinor vector space can induce a proper orthochronous Lorentz mapping on the Minkowski vector space The second part begins with a discussion of relativistic particle mechanics from both the Lagrangian and Hamiltonian points of view The book then turns to the relativistic classical field theory including a proof of Noether s theorem and discussions of the Klein Gordon electromagnetic Dirac and non abelian gauge fields The final chapter deals with recent work on classical fields in an eight dimensional covariant phase space

Covered with Deep Mist Dean Rickles, 2020-03-05 The problem of quantum gravity is often viewed as the most pressing unresolved problem of modern physics our theories of spacetime and matter described respectively by general relativity Einstein s theory of gravitation and spacetime and quantum mechanics our best theory of matter and the other forces of nature resist unification Covered with Deep Mist provides the first book length treatment of the history of quantum gravity focusing on its origins and earliest stages of development until the mid 1950s Readers will be guided through the impacts on the problem of quantum gravity resulting from changes in the two ingredient theories quantum theory and general relativity which were themselves still under construction in the years studied We examine how several of the core approaches of today were formed in an era when the field was highly unfashionable The book aims to be accessible to a broad range of readers and goes beyond a merely technical examination to include social and cultural factors involved in the changing fortunes of the field Suitable for both newcomers and seasoned quantum gravity professionals the

book will shine new light on this century old unresolved problem **The Principle of the Fermionic Projector** Felix Finster, 2006 The principle of the fermionic projector provides a new mathematical framework for the formulation of physical theories and is a promising approach for physics beyond the standard model This book begins with a brief review of relativity relativistic quantum mechanics and classical gauge theories emphasizing the basic physical concepts and mathematical foundations The external field problem and Klein's paradox are discussed and then resolved by introducing the fermionic projector a global object in space time that generalizes the notion of the Dirac sea At the mathematical core of the book is a precise definition of the fermionic projector and the use of methods of hyperbolic differential equations for detailed analysis The fermionic projector makes it possible to formulate a new type of variational principle in space time The mathematical tools are developed for the analysis of the corresponding Euler Lagrange equations A particular variational principle is proposed that gives rise to an effective interaction which shows many similarities to the interactions of the standard model The main chapters of the book are easily accessible for beginning graduate students in mathematics or physics Several appendices provide supplementary material which will be useful to the experienced researcher

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